EE 323
Electronics Instrumentations
Instructor: A. Dinh

**MIDTERM EXAMINATION**

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(Use the other sides of the papers if needed.)

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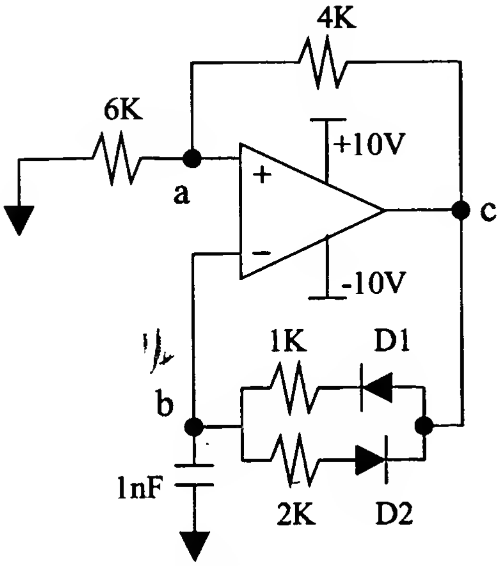
**Questions 1:** (20marks)

For the circuit below, make appropriate assumptions, sketch the waveforms at the op-amp terminals (i.e., node a, b, c).




Assume Ideal op-amp

$a = V_+ = \frac{R_1}{R_1+R_2} C$

12

Assume C initially uncharged

Charging

$V_b = 12 - (12) - (-12 + V_D) e^{-\frac{t}{RC}}$ use $R = 2k\Omega$ current will flow from b to c.

$= 12 - (24 - V_D) e^{-\frac{t_1}{(2k)(1\times10^{-9})}}$ when $t = t_1$ $V_b = 12V - V_D$

$12V - V_d = 12 - (24 - V_D) e^{\frac{-t_1}{(2k)(1\times10^{-9})}}$

$\frac{V_d}{24 - V_d} = e^{\frac{-t_1}{(2k)(1\times10^{-9})}}$

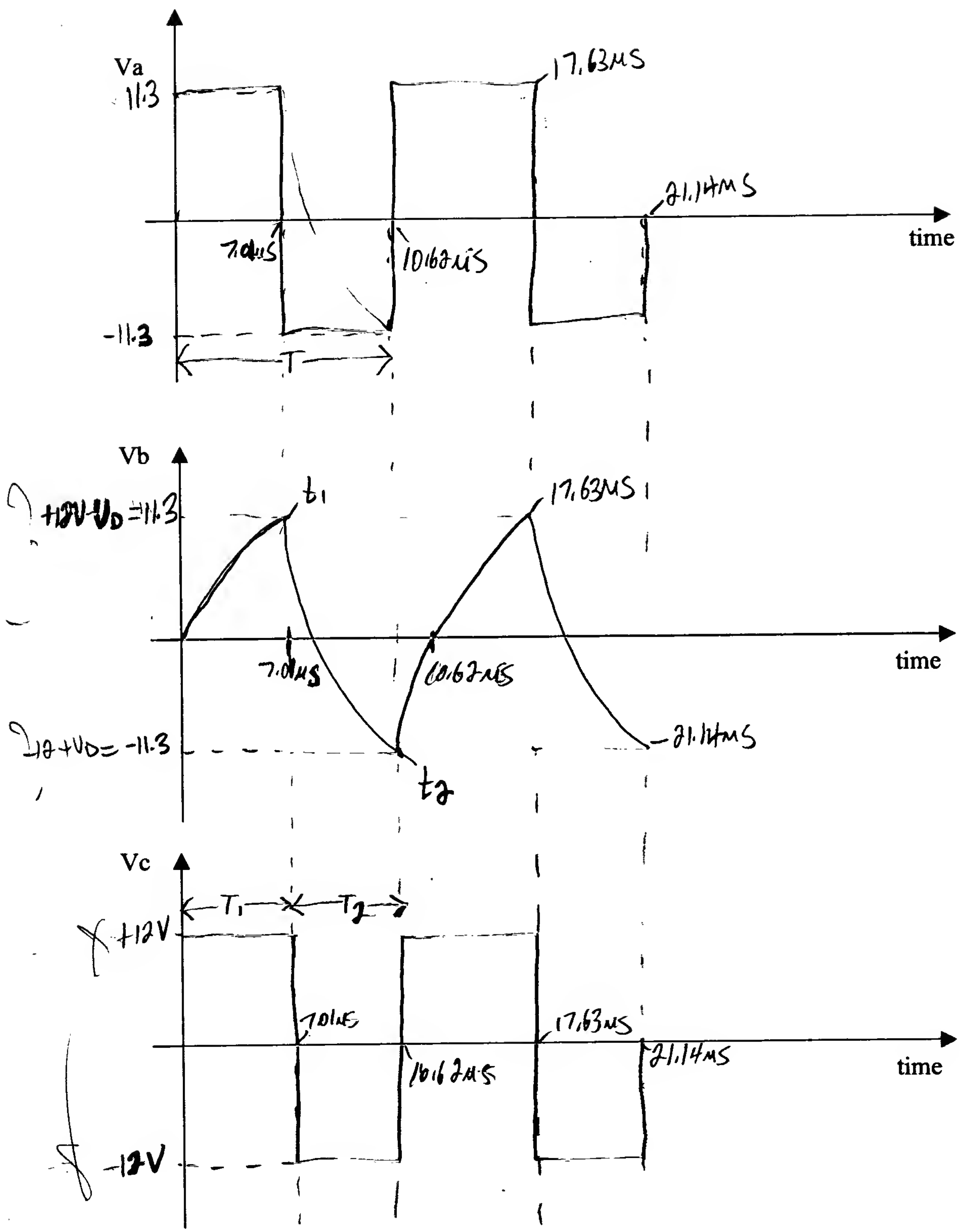
$\frac{t_1}{2k(1\times10^{-9})} = \ln\left(\frac{24 - V_d}{V_d}\right)$

$t_1 = 7.01\mu S$

In our case $t_1 \neq t_2$ b/c of different R btw b & C.

$t_2 = (1k)(1\times10^{-9}) \ln\left(\frac{24 - V_d}{V_d}\right) = 3.51\mu S$

$T = 7.01\mu s + 3.51\mu s = 10.62\mu S$


Va
11.3
17.63μS
21.14μS
time
7.01μS
10.62μS
-11.3
T
Vb
$t_1$
17.63μS
+12V-$V_D$=11.3
time
7.01μS
10.62μS
-12+$V_D$=-11.3
21.14μS
$t_2$
Vc
$T_1$
$T_2$
+12V
7.01μS
17.63μS
time
10.62μS
21.14μS
-12V

**Question 2:** (30marks)

*Part 1:*

An op-amp has the following open-loop transfer function:

$$A(j\omega) = \frac{v_{out}}{v_{in}} = \frac{10^5}{(1+j\frac{\omega}{\omega_1})(1+j\frac{\omega}{\omega_2})(1+j\frac{\omega}{\omega_3})}$$

where $\omega_1 = 100$rad/s, $\omega_2 = 10^3$rad/s, and $\omega_3 = 10^5$rad/s.

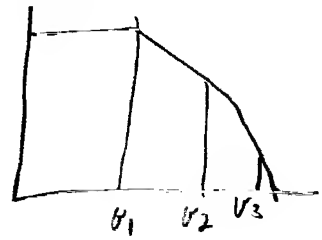
~~i.~~ If the op-amp is connected in a unity positive feedback configuration. What is the output frequency of the op-amp?

$A(j\omega) = 1$ in unity feedback

$\therefore 10^5 = \left|(1+j\frac{\omega}{\omega_1})(1+j\frac{\omega}{\omega_2})(1+j\frac{\omega}{\omega_3})\right|$

$\omega > \omega_3$ when gain $= 1$

$\boxed{\omega \approx 87000 \text{ rad/s}}$




X

$-100\,000$

~~ii.~~ If the op-amp is to be connected in a negative feedback configuration. What is the maximum feedback coefficient that can be tolerated before instability results? What is the minimum closed-loop gain of this op-amp without oscillation?

Find $\omega$

$-180° = -\tan^{-1}\left(\frac{\omega}{100\text{rad/s}}\right) - \tan^{-1}\left(\frac{\omega}{10^3\text{rad/s}}\right) - \tan^{-1}\left(\frac{\omega}{10^5\text{rad/s}}\right)$ 6

$\omega_{180} = 65928.55$ rad/s X

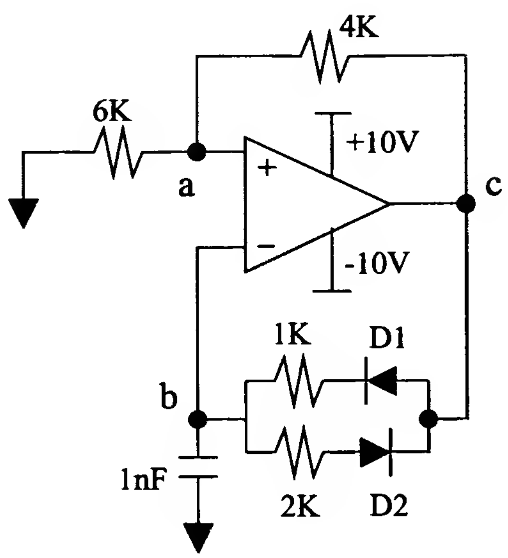
$A_{180} = \left|\frac{10^5}{(1+j(\frac{65929}{100}))(1+j(\frac{65929}{1000}))\cdot(1+j(\frac{65929}{100000}))}\right| = 1.92 \approx 2$

$\beta \leq \frac{1}{2} = \boxed{0.5}$

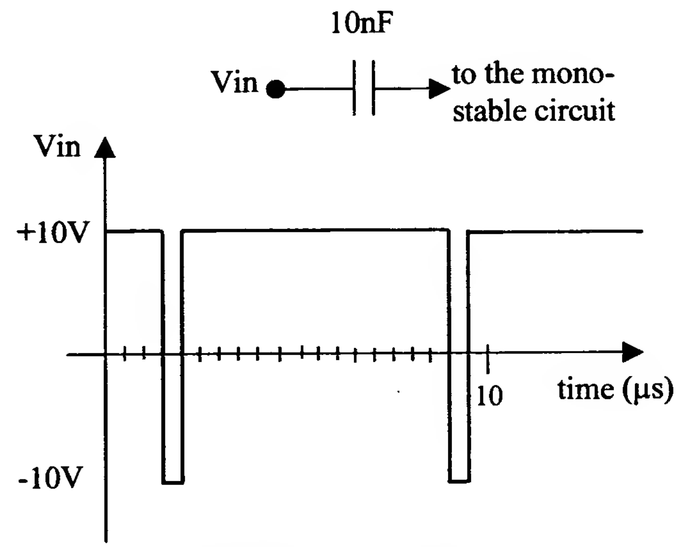
$\boxed{A_{CL} \geq 2}$

*Part 2:*

The circuit in Question 1 is shown below (a); without adding or deleting any component, re-arrange the circuit to make it function as a mono-stable circuit. Connect your circuit to the input Vin given in (b), sketch the waveforms at the op-amp terminals a, b, c of your modified circuit.

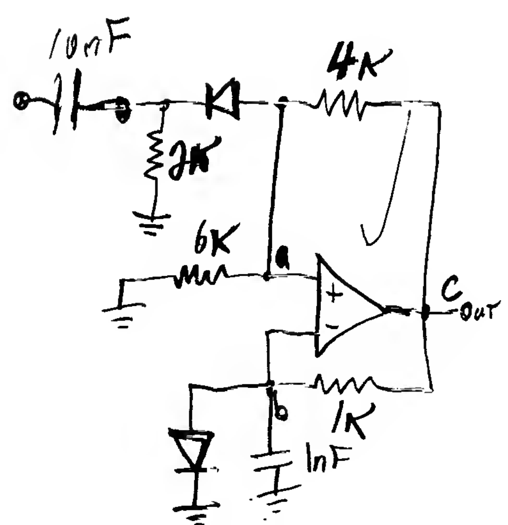


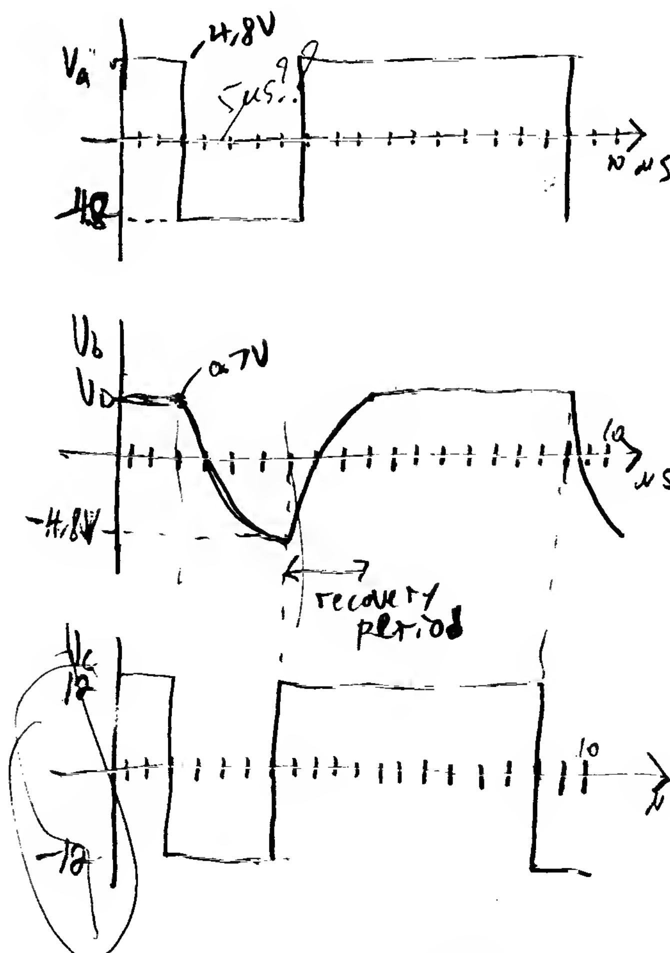

(a)




Input for the mono-stable circuit

(b)



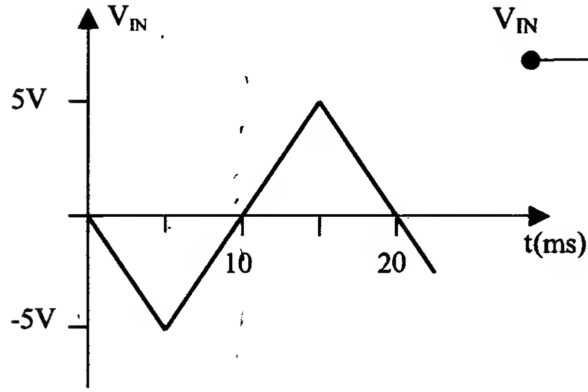



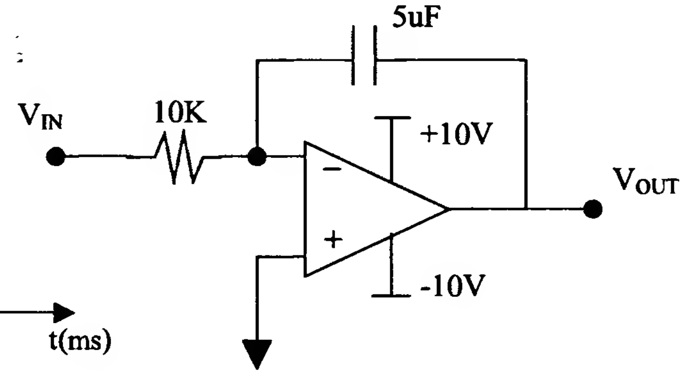

$\beta L_+ = \frac{4K}{10K}(12) = \pm 4.8V$

?

**Question 3:** (10marks)

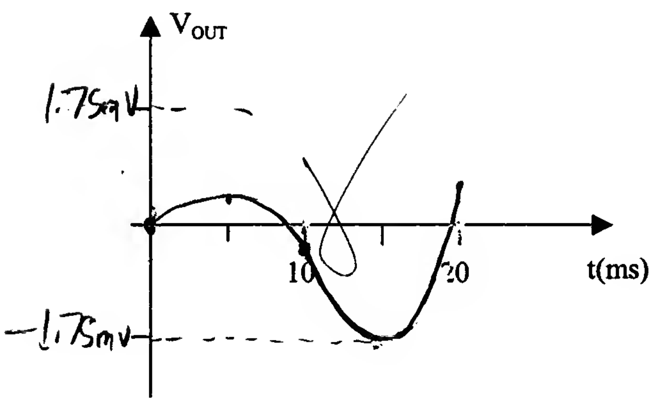
A 5V peak triangular voltage with a period of 20ms, depicted on the axis shown below, is applied to an ideal op-amp integrator. Sketch $V_{OUT}$ as a function of time. The capacitor has zero initial charge.




6

$$V_o = -\frac{1}{RC}\int V_i\,dt$$




bw 0-5

$$V_o = -\frac{1}{RC}\int_{0ms}^{5ms} -t\,dt = +\frac{1}{RC}\frac{1}{2}t^2\Big|_0^5 dt$$

$$= \frac{1}{RC}\frac{1}{2}(5ms)^2 = \frac{1}{(10k)(5\times10^{-6})2}(5\times10^{-3})^2 = 0.25\,mV$$

at $t = 5ms$ $V_{OUT} = 0.25mV$

at $t = 10ms$ $V_{OUT} = -0.5mV$

b/w 5-15ms

$$V_o = -\frac{1}{RC}\int_{5\times10^{-3}}^{15\times10^{-3}} t + V_{OUT} = \frac{-1}{(10k)(5\times10^{-6})}\frac{1}{2}t^2\Big|_{5ms}^{15ms} + 0.25mV = -1.75mV$$

at $t = 15ms$ $V_{OUT} =$

b/w 15ms-20ms

$$V_o = -\frac{1}{RC}\int_{15ms}^{20ms} -t + V_o = +\frac{1}{(10k)(5\times10^{-6})}\frac{1}{2}t^2\Big|_{15ms}^{20ms} - 1.75mV = 0$$



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